




# A shared frequency set between the historical mid-latitude aurora records and the global surface temperature

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## Abstract

Herein we show that the historical records of mid-latitude auroras from 1700 to 1966 present oscillations with periods of about 9, 10–11, 20–21, 30 and 60 years. The same frequencies are found in proxy and instrumental global surface temperature records since 1650 and 1850, respectively, and in several planetary and solar records. We argue that the aurora records reveal a physical link between climate change and astronomical oscillations. Likely in addition to a Soli-Lunar tidal effect, there exists a planetary modulation of the heliosphere, of the cosmic ray flux reaching the Earth and/or of the electric properties of the ionosphere. The latter, in turn, has the potentiality of modulating the global cloud cover that ultimately drives the climate oscillations through albedo oscillations. In particular, a quasi-60-year large cycle is quite evident since 1650 in all climate and astronomical records herein studied, which also include a historical record of meteorite fall in China from 619 to 1943. These findings support the thesis that climate oscillations have an astronomical origin. We show that a harmonic constituent model based on the major astronomical frequencies revealed in the aurora records and deduced from the natural gravitational oscillations of the solar system is able to forecast with a reasonable accuracy the decadal and multidecadal temperature oscillations from 1950 to 2010 using the temperature data before 1950, and vice versa. The existence of a natural 60-year cyclical modulation of the global surface temperature induced by astronomical mechanisms, by alone, would imply that at least 60–70% of the warming observed since 1970 has been naturally induced. Moreover, the climate may stay approximately stable during the next decades because the 60-year cycle has entered in its cooling phase.

## Highlights

- ▶ The paper highlights that global climate and aurora records present a common set of frequencies.
- ▶ These frequencies can be used to reconstruct climate oscillations within the time scale of 9–100 years.
- ▶ An empirical model based on these cycles can reconstruct and forecast climate oscillations.
- ▶ Cyclical astronomical physical phenomena regulate climate change through the electrification of the upper atmosphere.
- ▶ Climate cycles have an astronomical origin and are regulated by cloud cover oscillations.

## Introduction

Since ancient times people have claimed that climate and weather changes are partially related to cyclical astronomical phenomena linked to the orbits of the Sun, the Moon and the planets (Ptolemy, 1940, Ma'šar, 1886, Kepler, 1606, Swerdlow, 1998, Iyengar, 2009). Because of this conviction the ancient astronomers developed calendars that contain

several cycles (Aslaksen, 1999) as well as the well-known annual cycle. During the last 70 years, numerous scientific evidences appear to have corroborated that ancient conviction. For example, Milankovic (1941) theorized that variations in eccentricity, axial tilt and precession of the orbit of the Earth determine climate patterns such as the 100,000 year ice age cycles of the Quaternary glaciation. Milankovitch's theory fits the data very well, over the past million years, in particular if the temporal rate of change of global ice volume is considered (Roe, 2006). More recently, a number of authors (Shaviv, 2003, Shaviv and Veizer, 2003, Svensmark, 2007) have shown that the cosmic-ray flux records well correlate with the warm and ice periods of the Phanerozoic during the last 600 million years: in this case the cosmic-ray flux oscillations are believed to be due to the changing galactic environment of the solar system, as it crosses the spiral arms of the Milky Way. Over millennial and secular time scales several authors have found that changes in sunspot number and cosmogenic isotope productions well correlate with climate changes (Eddy, 1976, Sonett and Suess, 1984, Hoyt and Schatten, 1997, White et al., 1997, van Loon and Labitzke, 2000, Bond et al., 2001, Kerr, 2001, Douglass and Clader, 2002, Kirkby, 2007, Scafetta and West, 2005, Scafetta and West, 2007, Scafetta and West, 2008, Shaviv, 2008, Raspopov et al., 2008, Eichler et al., 2009, Soon, 2009, Meehl et al., 2009, Scafetta, 2009). Moreover, instrumental global surface records since 1850 appear to be characterized by a set of frequencies that can be associated to a Soli/Lunar tidal cycle (9.1-year period) and to the motion of the Sun relative to the barycenter of the solar system (about 10-10.5, 20-21, 30 and 60-62 year periods) (Scafetta, 2010a, Scafetta, 2010b).

In this paper, we study the historical mid-latitude aurora records since 1700 (Křivský and Pejml, 1988, Silverman, 1992) and show that these records share the same set of frequencies that characterize the climate system as well as the natural oscillations of the solar system. This finding reveals the existence of a clearer physical mechanism, missing in our previous study (Scafetta, 2010b), which could link the astronomical cycles to climate oscillations. The major implication of this paper is that there exists an astronomical harmonic modulation of the electric properties of the Earth's atmosphere that modulates the clouds and, therefore, the terrestrial albedo (Svensmark, 1998, Svensmark, 2007, Svensmark et al., 2009, Kirkby, 2007, Tinsley, 2008).

This research would also support the development of a novel astronomically based theory of climate change that may credibly compete and likely substitute the current mainstream anthropogenic global warming theory (AGWT) advocated by the IPCC (Solomon et al., 2007). In fact, the AGWT advocates claim that astronomical forcings of the climate are almost negligible and that the climate variations are induced by some still poorly understood and modeled red-noise-like *internal chaotic dynamics* of the climate system, and by trends in greenhouse gases (GHG) (mostly CO<sub>2</sub> and CH<sub>4</sub>) and aerosol records. More precisely, global surface temperature has risen (Brohan et al., 2006) by about 0.8 °C and 0.5 °C since 1900 and 1970, respectively. Solomon et al., 2007, Solomon et al., 2009 and other researchers (Lean and Rind, 2008) have claimed that more than 90% of the observed warming since 1900 and practically 100% of the observed warming since 1970 have had an anthropogenic cause. While Lean and Rind's methodology that the climate responds linearly with the forcings can be easily questioned by simply noting that the heat capacity of the climate system is not zero (Scafetta, 2009), the IPCC claims derive from Figures 9.5 and 9.6 in the IPCC report (AR4-WG1, 2007) showing, by means of professional climate general circulation models (GCMs), that natural forcings alone (volcano and solar irradiance) would have caused a cooling since 1970: the observed post-1970 warming has been interpreted as being induced by human activity alone. However, the very large uncertainty in the aerosol forcings and in the climate sensitivity to GHG changes (Solomon et al., 2007, Knutti and Hegerl, 2008, Rockström et al., 2009, Lindzen and Choi, 2011, Spencer and Braswell, 2011), and the current very poor modeling of the water vapor feedback (Solomon et al., 2010), of the cloud system (Lauer et al., 2010), of the ocean dynamics and of the biosphere question the robustness of the current GCMs for properly interpreting and reconstructing the real climate (Idso and Singer, 2009).

On the contrary, if a significant feature of the climate system is characterized by a specific set of harmonics, it may be possible to partially reconstruct and forecast it in the same way in which ocean tides are currently predicted, that is, by means of harmonic constituent models based on astronomical cycles (Thomson, 1881, Fischer, 1912, Doodson, 1921). A harmonic constituent model is just a superposition of several harmonic terms of the type

$$F(t) = A_0 + \sum_{i=1}^N A_i \cos(\omega_i t + \phi_i).$$

The frequencies  $\omega_i$  are deduced from astronomical theories. The amplitude  $A_i$  and the phase  $\phi_i$  of each harmonic are empirically determined using regression on an adequate sample of observations, and then the model is used to forecast future scenarios. Currently, in most US costal locations tidal forecast is made with 35–40 harmonic constituents (Ehret, 2008).

In the following, we show that in general typical energy balance models and general circulation models can be in first approximation mathematically reduced to harmonic models if they process harmonic forcings. Thus, we propose that the climate oscillations too can be approximately reconstructed and forecasted by using a planetary harmonic constituent model philosophically equivalent to Eq. (1) based on astronomical cycles.

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## Section snippets

### A possible link between mid-latitude auroras and the cloud system

In this paper, we postulate that the annual frequency occurrence of mid-latitude aurora events is a measure of the level of electrification of the global ionosphere, which is mostly regulated by incoming cosmic ray flux variations (Kirkby, 2007, Svensmark, 2007). When the Earth's magnetosphere is weaker relative to the surrounding space environment the ionosphere can be highly ionized by cosmic rays, and large auroras would more likely form at the mid-latitudes. This phenomenon would occur...

### A 60-year cycle in mid-latitude aurora and climate records

Fig. 1 shows the global surface temperature (HadCRUT3) (Brohan et al., 2006) from 1850 to 2010 (monthly sampled). Global surface temperature records (land, ocean, north hemisphere, south hemisphere) have been found to be characterized by a clear and large quasi-60-year cyclical modulation (Scafetta, 2010b). In fact, the following 30-year trends are evident in the record: 1850–1880, warming; 1880–1910, cooling; 1910–1940, warming; 1940–1970, cooling; 1970–2000, warming; and a small cooling since ...

### Spectral analysis of aurora and climate data, and joint power statistical tests

To determine whether faster cycles are equally common in the aurora and temperature records we analyze the global surface temperature and the auroras records by using the maximum entropy method (Ghil et al., 2002) because with a proper high number of *poles* this technique resolves the very low frequency band of the spectrum much better than Fourier or periodogram based techniques (Priestly, 2001). Note that in our case MEM needs to be used with a very large number of poles (up to half of the...

### A possible astronomical planetary origin of the aurora and temperature oscillations

The existence of common aurora and climate cycles suggests that the solar system planetary orbital dynamics may be their first physical cause. Indeed, some studies (Wolf, 1859, Schuster, 1911, Bendandi, 1931, Jose, 1965, Fairbridge and Shirley, 1987, Landscheidt, 1988, Landscheidt, 1999, Charvátová, 1990, Charvátová, 2000, Charvátová, 2009, Charvátová and Štěpánek, 2004, Grandpierre, 1996, Mackey, 2007, Hung, 2007, Wilson et al., 2008, Sidorenkov and Wilson, 2009, Perryman and Schulze-Hartung,...

### Further analysis of Jupiter and Saturn's orbital dynamics and of their induced solar system cycles

Herein we further analyze how the orbital eccentricities and the periods of Jupiter and Saturn can produce major 10, 20 and 60-year oscillations in the solar system. Fig. 6 shows the dates of all conjunctions of Jupiter and Saturn occurred from 1650 to 2010 relative to the Sun. In the figure it is assumed that the Earth's perihelion is fixed. The orbital data are obtained using the NASA Jet Propulsion Laboratory Developmental Ephemeris. The angular separation between Jupiter and Saturn relative ...

### Cloud cover oscillation as a possible mechanism for climate cycles

Total solar irradiance variations alone are usually claimed to be too small to induce large climate variations (Solomon et al., 2007). Additional solar related forcings would be necessary to explain climatic variations. Indeed, there may be

an additional effect on climate due to ultraviolet modulation of the stratospheric ozone and stratospheric water vapor (Stuber et al., 2001, Solomon et al., 2010), and a modulation of the cloud cover due to cosmic ray flux variation and a variation of the...

## Reconstruction and forecast of the climate oscillations based on aurora cycles

According Eq. (4), if we can assume that solar irradiance and/or the albedo periodically oscillate, then the temperature at the surface would also oscillate with a similar set of frequencies. In fact, at first approximation, the surface temperature variation would be proportional to the incoming irradiance  $\Delta F$  at the surface. The same result would be obtained also if the heat capacity of the Earth is taken into account. For example, a simple energy balance model could be given by a first order...

## Conclusion

Nineteen centuries ago, Ptolemy argued that the *motions of the aether* (that is the oscillations of the heliosphere) alter the uppermost part of the Earth's atmosphere (which was believed to be made of *fire*), which then alters the lower atmosphere *acting on earth and water, on plants and animals* (from Chapter 2 of the Tetrabiblos). Four centuries ago, Kepler explained that the earthly nature *could not help but respond to the dictates of heavenly harmonies*, and said that nature is affected by an...

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...A roughly 60-year periodicity is also a characteristic feature of many processes related to solar activity. This cycle is observed in the evolution of long-lived sunspot groups (Nagovitsyn and Pevtsov, 2016), large-scale magnetic fields on the Sun (Obridko and Shelting, 2000), auroral activity (Scafetta, 2012). The above data allow suggesting a possible link between long-term processes on the Sun and the evolution of large-scale circulation which, in turn, influences the character of solar activity effects on the lower atmosphere dynamics...

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